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Human subjects participated in this study after giving their free and informed consent. Investigators adhered to NAVHLTHRSCHCENINST 6500.2, 2 Aug 95, concerning the protection of human volunteers in medical research.

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SUMMARY

Problem.

Findings from a previous laboratory study indicated that naval personnel wearing an aviator anti-exposure suit (AES), the CWU-62/P, received the most protection from decreases in body temperature during intermittent exercise and waist-high cold-water exposure. The whole-body CWU-62/P suit prevented cold water from directly reaching the surface of the skin, thereby reducing body heat loss. However, wearing this suit during shipboard flooding repair operations may not be appropriate because the suit was designed primarily to minimize decreases in body temperatures of aviators during immersion in cold ocean waters. Thus, evaluation of other, more appropriately designed, whole-body anti-exposure suits (AESs) for use in shipboard flooding repair operations is required before identification of an appropriate AES can be determined.

Objective.

The purpose of the present investigation was to evaluate and compare the effectiveness of three whole-body AESs in minimizing decreases in body temperatures during simulated damage control activities and progressive cold-water immersion to midchest level.

Approach.

Fifteen male subjects were evaluated during progressive immersion in cold water (7.5°C/45.5°F). During immersion, subjects stood for 20 min in knee-level water, then 20 min in waist-level water followed by up to 40 min in water at midchest level. During each 10-min interval of immersion, each subject rested for 2 min and then performed 6 min of a pipe-patching task followed by 2 min of holding an 11.3-kg (25 lb) weight over his head. Subjects received a cold-water shower (7.5°C) from minutes 2 to 10, 22 to 30, 42 to 50, and 62 to 70. Maximum exposure time was 80 min. Each subject completed randomly ordered tests wearing (1) fire-resistant coveralls (CON), (2) Marine Corps experimental immersion suit (MARCOR), (3) Naval Clothing and Textile research facility experimental suit (NAVCLO), and (4) MultiFabs Survival™ suit (MULFAB).

Measures included rectal temperature (T_{re}), skin temperatures from the right upper chest (T_{ch}), right upper arm (T_{ar}), right index finger (T_{fi}), right midlateral thigh (T_{th}), right midlateral calf (T_{ca}), right big toe (T_{rto}), left big toe (T_{lto}), oxygen uptake ($\dot{V}O_2$), and heart rate (HR). T_{rto} and T_{lto} values were averaged to provide one toe (T_{to}) value. The effect of suit type on the dependent measures was examined using repeated measures analysis of variance and covariance.

Results.

Subjects were able to work significantly ($p < 0.05$) longer wearing MARCOR (73.6 min), NAVCLO (80 min), and MULFAB (75.5 min) than CON (47.2 min). However, differences in stay time between MARCOR, NAVCLO, and MULFAB were nonsignificant. Water leaks occurred most frequently in MARCOR (9 of 15 tests), MULFAB (3 of 15 tests), and NAVCLO (1 of 15 tests).

There were no significant differences in T_{re}, T_{fi}, or HR over time among suits. T_{ch} and T_{ar} for subjects wearing MARCOR, NAVCLO, and MULFAB increased throughout the test. The same temperatures (T_{ch} and T_{ar}) decreased in subjects wearing CON. Final in-water T_{ch} and T_{ar} of subjects wearing MARCOR, NAVCLO, and MULFAB were significantly higher compared with subjects wearing CON. Lower body skin temperatures for subjects wearing AES and CON decreased during immersion. Final in-water T_{th} was significantly higher for MULFAB compared with NAVCLO and MARCOR, which were higher than CON. Final in-water T_{ca} was significantly higher for subjects wearing MULFAB and NAVCLO compared with MARCOR and CON. However, T_{to} for subjects wearing MARCOR was significantly higher than for subjects wearing either MULFAB, NAVCLO, or CON.

Time integrals, the sum of minute-temperature values to 70 min, of T_{th} for subjects wearing MULFAB were significantly greater than while wearing NAVCLO and MARCOR, while time integrals of T_{ca} for subjects wearing MULFAB and NAVCLO were significantly greater than while wearing MARCOR. Time integrals of T_{to} for subjects wearing MARCOR were significantly greater than while wearing MULFAB or NAVCLO.

Conclusion.

MULFAB, followed by NAVCLO, provided the best overall protection against decreases in body temperatures during progressive immersion in cold water. The tight fit of MULFAB and NAVCLO, in contrast to the loose fit of MARCOR, appeared to be an important factor in the effectiveness of these AES. However, NAVCLO had the most durable suit design. These findings will aid in the future development of an AES designed specifically for shipboard flooding repair operations.

INTRODUCTION

U.S. Navy damage control personnel currently perform shipboard flooding operations dressed in dungarees or coveralls. However, these garments are inadequate for short-term or long-term cold-water exposure and can expose personnel to the risk of hypothermia (Keatinge, 1969; Horvath, 1982). Thus, the development and identification of protective ensembles for work in cold water (Steinman et al., 1987) is of interest to shipboard damage control personnel.

The findings from a previous laboratory study indicated that naval personnel wearing the whole-body CWU-62/P suit received the most protection from decreases in body temperature during intermittent exercise in waist-high cold water (Shannon et al., 1995). The CWU-62/P suit, acting like a "dry" suit, prevented cold water from directly reaching the surface of the skin, thereby, reducing body heat loss. However, this suit may be inappropriate for shipboard flooding repair operations because it was designed primarily as a survival suit to aid aviators immersed in cold ocean waters (Kaufman & Dejneka, 1985; White & Roth, 1979). Difficulty in donning the suit plus the costs of manufacturing and maintaining the suit make it inappropriate as a protective overgarment for damage control flooding operations.

Identification of whole-body anti-exposure suits (AESs) that minimize decreases in body temperature during cold-water flooding repair operations is of interest to naval personnel. However, before selection of an appropriate suit can be determined, evaluation of various AES concept designs is required. Therefore, the purpose of the present investigation was to evaluate and compare the effectiveness of three whole-body AESs in naval personnel in minimizing decreases in body temperatures during simulated damage control activities and progressive cold-water immersion to midchest level.

METHODS

The protocol and procedures used in this study were approved by the Committee for the Protection of Human Subjects of the Naval Health Research Center.

Subjects.

Fifteen active-duty U.S. Navy males served as subjects. The physical characteristics of the subjects were 29.6 ± 4.1 years, 173.6 ± 5.4 cm, 74.9 ± 7.4 kg, and 16.5 ± 6.0% body fat. The average peak oxygen uptake ($\dot{V}O_2$) from a maximal arm cycle ergometer test was 32.2 ± 5.2 $ml \cdot kg^{-1} \cdot min^{-1}$. All subjects were trained in shipboard damage control operations.

Medical Screening and Body Composition.

Each subject gave their informed consent prior to participation in testing. All subjects underwent medical screening which included a medical history questionnaire, body composition assessment, resting 12-lead electrocardiogram (ECG), and a maximal arm cycle ergometer test. Body surface area (m^2) was calculated according to DuBois' height and weight regression equation (Carpenter, 1964). A U.S. Navy regression equation was used to calculate percent body fat using height and circumference measures of the neck and abdomen (Hodgdon & Beckett, 1984).

Incremental Arm Cycle Ergometer Test.

All subjects completed an incremental arm cycle ergometer test to volitional exhaustion (Franklin, 1985). In this protocol, subjects exercised continuously and attempted to complete successive 2-min stages at 25, 50, 75, and 100 watts at an arm cycling rate of 50 rpm. After reaching 100 W, the arm cycling rate was increased every 2 min to 60, 70, and 80 rpm, respectively, until the subject reached exhaustion.

$\dot{V}O_2$ was measured using open-circuit spirometry, and heart rate (HR) was monitored by a 12-lead ECG. ECG electrodes were placed on each subject's chest in the Mason-Liker configuration. Two electrodes were placed on the upper chest near the shoulders (infraclavicular fossa), and two others were placed slightly above the waist at the base of the legs. Six electrodes (V_1-V_6) were also placed on the chest in the precordial position around the lower inside border of the left chest. Resting ECG and blood pressure (BP) were obtained from subjects in the supine, seated, and standing positions. BP was measured by auscultation prior to exercise and during recovery until resumption of pretest resting values.

Experimental Procedures.

All subjects performed four cold-water immersion tests. These tests were administered 1 week apart in random order. During these tests the subjects wore one of the following clothing ensembles:

1. Fire-resistant (Nomex) coveralls (CON), shorts, T-shirt, socks, safety boots, firefighter helmet, and Kevlar™ gloves
2. Marine Corps experimental immersion suit (MARCOR), coveralls, shorts, T-shirt, socks, safety boots, firefighter helmet, and Kevlar™ gloves
3. Naval Clothing and Textile Research Facility experimental suit (NAVCLO), coveralls, shorts, T-shirt, socks, safety boots, firefighter helmet, and Kevlar™ gloves

4. MultiFabs (MULFAB) Survival™ suit (Multifabs, Derby DE28 8LF, UK), coveralls, shorts, T-shirt, socks, safety boots, firefighter helmet, and Kevlar™ gloves.

The MARCOR, NAVCLO, and MULFAB AESs are single-piece suits designed for exposure to cold water. The MARCOR suit is made of a clear urethane (plastic) material and has vinyl booties. It has two elastic drawstrings, one to close a hood around the face and neck and another to close the shoulders around the neck. The wrists, waist, and ankles are fitted to the body with elastic straps and snaps. With MARCOR, the safety boots are worn inside the plastic bag suit. The NAVCLO suit is made of polyvinyl chloride-coated cotton. However, the foot booties and wrist and neck seals of the suit are constructed of closed-cell neoprene. A water-shielded zipper placed horizontally across the upper back allows entrance to the suit. The MULFAB suit is made of 100% polyurethane-coated vinyl. The suit has feet and a hood made of the same material and a waterproof zipper placed vertically over the chest and abdomen.

The subjects were instructed to abstain from exercise for 24 hr prior to each cold-water test and to consume at least two glasses (16 oz) of water the night before the test. Hydration status was determined by measuring the specific gravity of a urine sample obtained prior to the test. During the cold-water test, subjects stood on a 3-step platform, which was placed in a SwimEx SWXF-400 Aquatic Exercise Machine (SwimEx Systems, Inc.; Warren, RI). The first step raised the water level to the knees, while the second and third steps raised the water level to the waist and midchest, respectively. The water temperature averaged 7.5 ± 0.6°C (45.5°F), and the water flow rate was set at 0.45 $m \cdot s^{-1}$ (1 mph). The room air temperature averaged 23.6 ± 1.8°C (77°F).

In the cold-water immersion protocol, subjects initially stood for 20 min in knee-level water, followed by 20 min in waist-level water and 40 min in water at the midchest level, respectively. During each 10-min interval, each subject rested for 2 min then performed muscular work consisting of 6 min of a pipe-patching task followed by 2 min of holding an 11.3-kg (25 lb) weight over his head. Subjects received a cold-water shower (7.5°C) from minutes 2 to 10, 22 to 30, 42 to 50, and 62 to 70. During the pipe-patching task, subjects attempted to apply and tighten a stainless steel repair clamp around a 4-inch-diameter pipe with an open-end wrench. The pipe was adjusted to remain at the same height above the head as the subject was progressively lowered into the water.

The test was terminated when the subject reached the maximum allowable cold-water exposure time of 80 min, an end point criteria based on signs or symptoms of hypothermia or

hyperthermia, or when the subject reached volitional fatigue. The termination criteria for hypothermia were a decrease in rectal temperature (T_{re}) to less than 35.5°C (95°F) at any time, or a body skin temperature of 10°C (50°F) or lower for a 10-min period. The termination criterion for hyperthermia was an increase in T_{re} to more than 39.5°C (103.1°F) for any level of time. HR responses resulting in termination included an exercise HR above 90% of maximum for 5 min, a resting HR above 80% of maximum for 5 min, an HR above 210 bpm at any time, or a systolic BP above 200 mmHg. In addition, tests were terminated if subjects experienced nausea, dizziness, or disorientation.

Measurements.

Prior to each test, subjects inserted a rectal thermistor to a depth of 20 cm in the rectum for the T_{re} measurement. Skin temperatures were measured using thermistors placed at the right upper chest (T_{ch}), right upper arm (T_{ar}), right index finger (T_{fi}), right midlateral thigh (T_{th}), right midlateral calf (T_{ca}), right big toe (T_{rto}) and left big toe (T_{lto}). Right T_{rto} and left T_{lto} values were averaged to provide one T_{to} value. ECG electrodes were placed on the chest to monitor HR. T_{re}, T_{ch}, T_{ar}, T_{fi}, T_{th}, T_{ca}, and T_{to} were recorded at 1-min intervals by a portable Squirrel data logger (Science/Electronics; Miamisburg, OH) worn outside the ensemble and placed on the side of the flume away from the water. HR was also recorded by a Polar Heartwatch System (Polar, USA, Inc.; Stamford, CT).

Pulmonary minute ventilation ($\dot{V}_E$), $\dot{V}O_2$, and carbon dioxide production ($\dot{V}CO_2$) were measured during the rest prior to immersion and during the immersion exercise periods by open-circuit spirometry (Sensormedics 2900; Yorba Linda, CA). These measurements were taken between minutes 12 to 20, 32 to 40, 52 to 60 and 72 to 80. The ratio of $\dot{V}O_2$ to $\dot{V}CO_2$ represented the respiratory exchange ratio (RER).

Total-body sweat loss was calculated as the difference in pretest and posttest body weight after adjustment of the posttest weight for urine output and water intake. Subjects were provided with water ad libitum during the rest periods. Fluid balance was calculated as water intake minus urine output and sweat loss.

Statistical Analysis.

The SAS® System software (SAS Institute, Inc.; Cary, NC) was used for statistical analysis of the data. Stay time, lower body temperature integrals, and metabolic and fluid balance data were analyzed by one-way analysis of variance (ANOVA). Stay time was defined as the total time of cold-water immersion. The lower body temperature integrals equaled the sum of temperature values taken every minute during 70 min of cold-water exposure. The impact of

suit and time on HR, T_{re}, T_{ch}, T_{ar}, T_{fi}, T_{th}, T_{ca}, and T_{to} were analyzed by ANOVA. End stay time T_{re}, T_{ch}, T_{ar}, T_{fi}, T_{th}, T_{ca}, and T_{to} were analyzed by repeated measures analysis of covariance (ANCOVA) using preexposure values as covariates. Post hoc analyses were performed by Least Squares Means test. The significance level was set at alpha equal to 0.05.

RESULTS

Stay Time.

Subjects wearing MARCOR, NAVCLO, and MULFAB had significantly ($p < 0.05$) longer stay times in comparison with wearing CON (Table 1). Differences in stay time between subjects wearing MARCOR, NAVCLO, and MULFAB were nonsignificant.

Table 1. Comparison of mean (±SD) stay times (n = 15).

Variable	CON	MARCOR	NAVCLO	MULFAB	Comparisons ($p < .05$)
Stay time (min)	47.2 ± 14.9	73.6 ± 13.8	80.0 ± 0.0	75.5 ± 7.1	MARCOR, NAVCLO, MULFAB > CON

Metabolic, Heart Rate, Pipe Patch, and Fluid Balance Responses.

No significant differences were found among suits with respect to either metabolic rates or HR. Prior to immersion, resting $\dot{V}_E$ averaged 11.3 ± 2.0 L·min^{-1}. Resting $\dot{V}O_2$ averaged 313 ± 42 ml·min^{-1}, $\dot{V}CO_2$ averaged 240 ± 35 ml·min^{-1}, and RER averaged 0.76 ± 0.05. Throughout immersion, exercise metabolic rate during pipe patching remained constant. $\dot{V}_E$ averaged 22 ± 5 L·min^{-1}, $\dot{V}O_2$ averaged 716 ± 126 ml·min^{-1}, and $\dot{V}CO_2$ averaged 539 ± 108 ml·min^{-1}. The exercise RER averaged 0.75 ± 0.04, and the energy expenditure averaged 237 ± 42 W. During immersion, no significant differences were found among the subjects wearing the different suits for either average resting HR (78 ± 3 bpm) or average exercising HR (89 ± 4 bpm)(Figure 1). No differences were found over time or among subjects wearing the different suits for the number of pipe patches per work session (7 ± 2 patches per session).

There were no significant differences among subjects wearing an AES and CON for water intake, urine output, sweat loss, or fluid balance. Water intake for subjects (n = 15) wearing an AES and CON averaged 66 ± 154 ml, while urine output averaged 54 ± 162 ml. The average sweat loss was 156 ± 131 ml, while the fluid balance averaged -144 ± 239 ml.

Cold-Water Immersion Responses.

Table 2 summarizes the results of the analysis of end stay time and absolute low temperatures.

Table 2. Comparison of end stay time body temperatures (°C) and heart rate (n = 14).

Variable	**CON**	**MARCOR**	**NAVCLO**	**MULFAB**	**Comparisons** ($p < 0.05$)
T_{re}	36.94 ± 0.21	36.80 ± 0.21	36.77 ± 0.21	36.78 ± 0.21	N.S.
T_{ch}	29.89 ± 0.71	35.23 ± 0.65	35.36 ± 0.65	35.77 ± 0.67	MARCOR, NAVCLO, MULFAB > CON
T_{ar}	27.52 ± 0.57	34.58 ± 0.52	34.56 ± 0.53	34.93 ± 0.54	MARCOR, NAVCLO, MULFAB > CON
T_{fi}	21.75 ± 0.63	21.48 ± 0.62	19.96 ± 0.62	20.17 ± 0.64	N.S.
T_{th}	11.51 ± 0.68	15.25 ± 0.62	16.04 ± 0.63	19.38 ± 0.65	MULFAB > NAVCLO, MARCOR > CON
T_{ca}	10.44 ± 0.53	11.19 ± 0.48	13.63 ± 0.48	14.37 ± 0.51	MULFAB, NAVCLO > MARCOR, CON
T_{to}	12.12 ± 0.90	17.33 ± 0.91	13.24 ± 0.88	11.56 ± 0.92	MARCOR > NAVCLO, MULFAB, CON

Values represent least square means ± SE.

There were no significant differences in T_{re} among suits. The mean T_{re} responses for the four suits showed only slight decreases during immersion (Figure 2). The T_{ch} and T_{ar} for subjects wearing MARCOR, NAVCLO, and MULFAB were significantly higher compared with subjects wearing CON (Figures 3 and 4). T_{ch} and T_{ar} for subjects wearing MARCOR, NAVCLO, and MULFAB all remained at pretest levels throughout immersion. However, T_{ch} and T_{ar} dipped slightly during the shower phases of immersion. For CON, T_{ch} and T_{ar} decreased nonsignificantly during the first and second shower periods, but they increased during the nonshower periods.

Differences in T_{fi} for subjects wearing MARCOR, NAVCLO, MULFAB, and CON were nonsignificant (Figure 5). T_{fi} dropped continuously throughout immersion. T_{fi} for subjects wearing an AES and CON decreased rapidly during the initial shower periods and maintained low values throughout immersion.

During the first 20 min of immersion to the knees, T_{th} decreased slightly for subjects wearing an AES and CON (Figure 6). With immersion to the waist, T_{th} dropped significantly. Among AESs, temperature integrals for T_{th} were significantly higher for subjects wearing MULFAB compared with subjects wearing MARCOR and NAVCLO (Table 3).

During the first 20 min of immersion to the knees, T_{ca} decreased for subjects wearing an AES and CON (Figure 7). The decrease for subjects wearing CON was greater than while wearing MULFAB, NAVCLO, and MARCOR. However, with immersion to the waist, T_{ca} for subjects wearing MULFAB, NAVCLO, and MARCOR decreased rapidly and continued to decline slowly throughout the remainder of the test. Final T_{ca} at the end of immersion for subjects wearing MULFAB and NAVCLO were significantly higher than while wearing MARCOR and CON (Table 2). Among AESs, T_{ca} integrals were significantly higher for subjects wearing MULFAB and NAVCLO compared with subjects wearing MARCOR (Table 3).

During immersion, T_{to} decreased for subjects wearing an AES and CON (Figure 8). Movement from knee-high to waist-high water immersion had a minor effect on T_{to} for subjects wearing MULFAB, NAVCLO, and MARCOR. Final T_{to} at the end of immersion was significantly higher for subjects wearing MARCOR compared with wearing NAVCLO, MULFAB, and CON. Temperature integrals were significantly higher for subjects wearing MARCOR than while wearing either MULFAB or NAVCLO.

Table 3. Comparison of lower body skin temperature integrals during cold-water immersion (n = 8).

Variable	**MARCOR**	**NAVCLO**	**MULFAB**	**Comparisons** ($p < 0.05$)
T_{th}	1741 ± 69	1933 ± 69	2108 ± 69	MULFAB > NAVCLO, MARCOR
T_{ca}	1216 ± 35	1393 ± 35	1593 ± 35	MULFAB, NAVCLO > MARCOR
T_{to}	1974 ± 130	1691 ± 130	1495 ± 130	MARCOR > MULFAB, NAVCLO

Values represent least square means ± SE.

DISCUSSION

In a previous study (Shannon et al., 1995), the authors evaluated the effectiveness of "wet" and "dry" AES designs to minimize decrements in body temperature during immersion in waist-deep cold water. It was reported that decreases in body temperatures were minimized to the greatest extent in subjects wearing a whole-body "dry" AES. In the present study, we extended the evaluation of AES designs by comparing the effectiveness of three types of whole-body "dry" AESs in minimizing decreases in body temperatures during progressive cold-water immersion. The findings from the current study along with those of Shannon et al. demonstrate the superiority of the "dry" AES design concept in preventing excessive body heat loss. The findings also suggest that an AES for use during shipboard flooding repair operations be developed using the "dry" design concept.

The present study attempted to simulate a shipboard flooding scenario by having subjects experience progressive water immersion to midchest level, endure intermittent cold-water showers, and perform repetitive cycles of rest and muscular work (pipe-patching immediately followed by holding a weight over the head). This protocol is in contrast to the one executed by Shannon et al. (1995) in which subjects experienced waist-high water immersion and performed repeated cycles of rest and arm cycle ergometry at 64% of arm VO_2 peak with no shower periods.

Stay Time.

In the present study, subjects wearing CON recorded average stay times of 47 min. This time is lower than those of subjects wearing CON (61 min) reported by Shannon et al. (1995). The lower stay time is likely due to upper body cooling associated with the repetitive cold-water showers. However, stay times for subjects wearing MARCOR, NAVCLO, and MULFAB averaged 73.6, 80.0, and 75.5 min, respectively. It is possible that upper body cooling, due to the intermittent showers periods, may have helped to reduce MARCOR and MULFAB stay times.

In the previous study, stay times for subjects wearing the two surface deck suits, which functioned as "wet" suits, averaged 72.5 min for the Navy Cold Weather suit and 76.4 min for the Mustang™ suit, while the stay time for the "dry" CWU-62/P suit averaged 77.9 min. However, while the stay times for subjects wearing "wet" and "dry" AESs were similar, the "wet" AES design has the potential to limit mobility. It is possible that during flooding repairs the polyvinyl chloride foam comprising the inner material of the "wet" AES could trap a large volume of water making it difficult to lift the arms. Also, it would be necessary to drain water from the suits before subjects could move to a warm environment and commence recovery. Thus, our findings from this and the previous study confirm that stay time in cold water is longest for whole-body "dry" AES designs.

Body Fat, AES, and Body Temperature Responses

Individuals with a large amount of subcutaneous fat tolerate cold-water exposure better than lean individuals (Hayward & Keatinge, 1981; Keatinge, 1969). A large amount of subcutaneous fat is related to a slower rate of decline in core temperature (Keatinge, 1969).

According to Nunneley et al. (1985) subcutaneous fat reduces heat loss, even when heavy clothing is worn. However, while body fat percentages of the subjects ranged from 9% to 29%, there were no differences in T_{re} or skin temperatures between lean and fat subjects for any of the suits. This finding is similar to that found in the previous study (Shannon et al., 1995). The findings from both of these studies support the findings of Toner et al., (1989) who reported that wearing a whole-body AES in cold water attenuates differences in heat loss normally seen between fat and lean people. Low-fat individuals when compared with high-fat individuals may be able to maintain higher body temperatures because of a significantly greater shivering thermogenesis (Glickman-Weiss et al., 1991). Thus, our findings suggest that individual subcutaneous fat levels will not modify body temperature response patterns of subjects wearing a whole-body AES and experiencing progressive immersion to midchest.

Rectal Temperature Responses

Immersion in cold water promotes a decline in core temperature. Hayward and Eckerson (1984) reported a rate of decline in T_{re} of 6.0°C•hr^{-1} for nude subjects immersed to the neck in 10°C water. However, the rate of decline for subjects wearing whole-body AES has been reported as 0.13°C•hr^{-1} (Hayward, 1984) or less (White & Roth, 1979). In our present study, the T_{re} response was similar among subjects wearing CON and an AES and remained constant between 37.0°C to 37.2°C throughout progressive immersion. However, there was a tendency for T_{re} to decline slightly in subjects wearing CON during the last 20 min of immersion, and in subjects wearing an AES during the last 40 min of immersion. The consistency of T_{re} is likely due to the shunting of warm blood into the thorax due to peripheral vasoconstriction, and to an increase in metabolic heat production due to shivering and muscular work (Hayward et al., 1978; Hayward & Eckerson, 1984). The slight decline in T_{re} appears to be the result of convective heat loss due to thermal gradients between skin and air, skin and water, and upper and lower body regions above and below the water line, respectively (Bristow et al., 1994).

Metabolic Responses

$\dot{V}O_2$ during muscular work was similar for subjects wearing CON and an AES, and equivalent for all levels of body immersion. While direct measures of shivering were not made, it was possible to visually identify shivering among subjects during immersion. All subjects wearing CON shivered during immersion, but incidence of shivering in subjects wearing an AES was less. The consistency of $\dot{V}O_2$ among subjects wearing CON and an AES suggests that shivering contributed little to the metabolic response during muscular work and did not significantly modify the number of clamps secured during the pipe-patching task.

Prolonged immersion in cold water promotes an increase in metabolic rate as T_{re} gradually decreases (Hayward et al., 1977). Exercise in cold water potentiates the drop in T_{re} and increases convectional heat loss (Keatinge, 1969). However, in the present study, muscular work did not accelerate heat loss. This is likely due to the execution of the pipe-patching and weight-holding tasks with the shoulders, arms, and hands out of the water. This suggests that the low $\dot{V}O_2$ (716 ml•min^{-1}) associated with the pipe-patching and weight-holding tasks are related to the type of muscle contraction and amount of muscle mass used during work (Lewis et al., 1985). Our findings suggest that energy expenditure associated with pipe-patching and shoring (as suggested

by the weight-holding task) will be low, and that heat production during these activities may not be large enough to counteract decreases in body heat content.

Heart Rate Responses

HR was similar for subjects wearing CON and an AES. The similarity in HR is consistent with the constant metabolic rate and lack of change in T_{re} throughout immersion. Immersion in cold water to the waist and midchest is known to increase stroke volume and lower HR as blood from the periphery is shunted into the central circulation (Haffor et al., 1991). However, in the present study, this effect does not seem to have occurred because HR during rest and work was unaffected by the different levels of immersion.

Sweat Loss and Fluid Balance

There were no significant differences among subjects wearing the different suits for sweat loss or fluid balance. In the previous study (Shannon et al., 1995) sweat loss averaged 394 ml throughout immersion, while in the present study, sweat loss averaged 156 ml. However, in the present study fluid balance averaged -144 ml which is comparable to the -127 ml reported for subjects in the Shannon et al. study. These findings indicate that heat production from arm cycling ergometry and the pipe-patching and weight-holding tasks more than compensated for heat loss from the lower body. The higher sweat loss in the Shannon et al. study reflects the larger exercise heat production associated with arm ergometer exercise (492 W) compared with that for the pipe-patching and weight-holding tasks (237 W). The lower sweat loss in the present study may also reflect a greater amount of convective heat loss due to the shower/nonshower cycles. Our findings suggest that fluid balance is maintained in subjects wearing whole-body "dry" AES and performing low-intensity muscular work in cold water. This finding suggests that fluid balance will not be a serious problem for personnel allowed ad libitum water intake and performing shipboard flooding repair operations in cold water lasting up to 80 min.

Skin Temperature Responses

Immersion in cold water to the neck in nude subjects produces a rapid decrease in skin temperatures (Hayward & Eckerson, 1984). However, wearing a whole-body AES substantially reduces the rate of decline in skin temperature (Hayward, 1984). The average T_{ch} and T_{ar} for subjects wearing an AES ranged between 35°C and 36°C throughout immersion. These relatively high values likely reflect a reduction in evaporative and dry-heat exchange due to the insulation and impermeable material comprising the various AESs. However, these T_{ch} and T_{ar} values are lower than the values reported in the Shannon et al. (1995) study, which ranged from 36°C to 37°C. The lower temperatures are likely due to the cooling effect of the intermittent shower cycles.

The T_{ch} and T_{ar} responses for subjects wearing an AES fluctuated slightly in response to the shower/nonshower cycles. However, for subjects dressed in CON, T_{ch} and T_{ar} fluctuated substantially in response to the shower cycles. Hayward et al., (1973) showed that the upper chest and lateral thorax are the major avenues for heat loss during cold-water exposure to the neck. The large upper body skin temperature changes for CON were likely related to alternating increases and decreases in sympathetic neural outflow in synchrony with the shower and

nonshower periods, respectively (Horvath, 1982). The fluctuating T_{ch} and T_{ar} values suggest that during the shower periods, vasoconstriction in skeletal muscle and skin reduced these temperatures by shunting warm blood to the central circulation, while during the nonshower periods warm blood returned to muscle and the cutaneous vasculature. Thus, the higher T_{ch} and T_{ar} for subjects wearing an AES demonstrate that the whole-body AES helped to maintained upper body temperatures during the shower/nonshower cycles and throughout progressive immersion.

T_{fi} dropped rapidly during the first shower period. T_{fi} remained low during the first nonshower period, and it continued to decrease gradually with successive shower/nonshower cycles. This response was similar for all AESs and was due to the fact that all subjects wore the same type of water-permeable gloves. Thus, despite higher upper body temperatures with an AES, T_{fi} was dependent on water temperature. It has been shown that a hand skin temperature between 13°C and 18°C is critical to impairment of manual performance (Clark & Cohen, 1960). However, Chen et al. (1996) showed the existence of large variability in skin temperature at various sites on the hand and fingers. Our findings suggest that damage control work gloves should be made of a water-impermeable material. Keeping water off the fingers and hands might minimize decreases in hand and finger temperatures and allow maintenance of fine-motor-skill dexterity.

The impact of an AES on body temperature responses is most evident for the T_{th}, T_{ca}, and T_{to}. T_{th}, T_{ca}, and T_{to} decreased during progressive immersion for subjects wearing CON and an AES. However, the response patterns varied for each leg segment and among all suits. For example, during immersion to the knees, T_{th} decreased slightly for subjects wearing CON, but remained constant for subjects wearing an AES. With movement to waist-high water, T_{th} for subjects wearing CON and an AES decreased rapidly. However, the response pattern differed among suits with T_{th} for subjects wearing MULFAB maintaining the highest values, followed by NAVCLO, MARCOR, and CON (Figure 6). The T_{th} integrals also were highest for subjects wearing MULFAB compared with subjects wearing NAVCLO and MARCOR (Table 3). This suggests that temperature gradients between core, intermittent, and superficial thigh temperatures were smallest for MULFAB (Bristow et al., 1994). The lower T_{ca} integral for MARCOR may reflect reduced insulation due to compression of the suit by the water (Goldman et al., 1966). Thus, the higher T_{th} for subjects wearing MULFAB and NAVCLO suggests lower convective heat loss as a result of higher insulation levels.

During immersion to the knees, T_{ca} decreased for subjects wearing CON and an AES. However, T_{ca} for subjects wearing MULFAB were highest, followed by NAVCLO, MARCOR, and CON (Figure 7). With movement to waist-high water, the T_{ca} again decreased with the rank order among AESs and CON remaining unchanged. The second decrease in T_{ca} occurred with the lower legs already below the water line. This suggests that the secondary decline in T_{ca} was related to a further shunting of warm blood from the lower legs to the central circulation as a result of a further increase in peripheral vasoconstriction and hydrostatic pressure.

While T_{ca} decreased continuously throughout progressive immersion, the response patterns for subjects wearing CON and an AES differed. The highest T_{ca} recorded was for subjects wearing MULFAB, followed by NAVCLO, MARCOR, and CON. However, the T_{ca} integrals were similar for subjects wearing MULFAB and NAVCLO, but higher in comparison with subjects wearing MARCOR (Table 3). Again, MULFAB and NAVCLO appear to reduce temperature gradient within the lower leg (Bristow et al., 1994). Thus, the higher final T_{ca} and T_{ca} integrals for subjects wearing MULFAB and NAVCLO suggest that these AESs are associated with a lower convective heat loss possibly as a result of a greater amount of insulation.

During immersion to the knees, T_{to} decreased for subjects wearing CON and an AES. For subjects wearing CON, the rate of decrease was initially rapid, but then became gradual throughout the remainder of immersion (Figure 8). Unlike T_{th} and T_{ca}, movement from knee-high water to waist-high water did not produce a rapid or large decrease in T_{to}. However, there were substantial differences among subjects wearing an AES, with the slowest rate of decline occurring for subjects wearing MARCOR, followed by NAVCLO and MULFAB. During the immersion, the final T_{to} and T_{to} integrals were highest for subjects wearing MARCOR compared with NAVCLO and MULFAB. This was due to the large insulation capacity of the safety boots and to the fact that the safety boots were worn inside MARCOR. Thus, the MARCOR configuration provided the best protection against decreases in $T_{to.}$

Implications for the Design of Future Damage Control AESs.

An important feature of a whole-body AES designed for shipboard flooding repair should be its insulation capacity, and hence its ability to minimize convective heat loss. As shown for "wet" and "dry" AESs, designed for survival in ocean waters, reductions in convective heat loss occur best through the use of insulation foam or air-trapping clothing inside the suit (Hayward et al., 1978; Steinman et al., 1987). An AES designed for shipboard flooding repair operations should provide thermal protection over the head, arms, torso, legs, and feet using a whole-body encapsulated design that prevents water from making direct contact with the skin. Consideration should also be given to distribution of insulation within the AES. As Shender et al., (1995) reported, the most to least sensitive body segments to changes in insulation level are the chest and abdomen, followed by the legs, head, and arms. Our findings are consistent with previous findings (Clark & Cohen, 1960) showing that maintenance of hand and finger temperature is critical if fine motor skill is to be retained. However, the insulation level of the AES should not be so large as to promote heat strain in personnel working on repairs.

During the present study, some AESs developed leaks. Normal handling and use seemed to be the cause for the leaks. However, these leaks did not significantly impact body temperature responses used to evaluate the effectiveness of the suits to minimize body heat loss. The ability of an AES to withstand leaks is an important factor to be addressed in the development of AES for damage control operations. As shown by Allen et al., (1985) leaks can substantially increase convectional heat loss. In our present study, we recorded leaks in 1 of 15 NAVCLO tests, 3 of 15 MULFAB tests, and 9 of 15 MARCOR tests. The durability of NAVCLO was likely due to the polyvinyl chloride material used for the suit.

While we found differences in lower body temperatures among subjects wearing the different AESs, each AES possessed design features or insulation characteristics that could be incorporated into future AES designs. For example, MARCOR, a one-size-fits-all "plastic bag" design, provided the best protection to the feet against cold water. This occurred because the subject wore his safety boots inside the suit, thereby increasing significantly insulation around the feet and toes. However, the suit, constructed of urethane, was thin and susceptible to punctures, abrasions, and rips to the seams.

MULFAB was the easiest to put on by subjects primarily because the zipper was in the front of the suit. Two important characteristics of this AES were the tight-fitting head hood and wrist seals. MULFAB also provided the best protection against decreases in T_{th} and T_{ca}. However, MULFAB was susceptible to leakage due to abrasion, and punctures, and thus required constant repair with a waterproof sealant.

The NAVCLO suit was similar to the MULFAB in minimizing decreases in T_{th}, T_{ca}, and T_{to}. Distinguishing characteristics of NAVCLO were the neoprene booties which provided additional insulation to the feet and toes. The NAVCLO suit material was very durable. However, NAVCLO was difficult to don because the suit required subjects to enter through a zipper across the upper back. This required assistance from another individual. Another problem with NAVCLO was that the entry zipper was not waterproof. Thus, as currently configured, leakage can occur with this suit if immersion is beyond shoulder level. However, this problem can be solved using a waterproof zipper.

Conclusions.

The major findings from this study are (1) subjects were able to achieve significantly longer cold-water stay times while wearing the MARCOR, NAVCLO, and MULFAB compared with the CON; (2) MULFAB provided the best overall protection against decreases in body temperatures and was also the easiest suit to don; (3) NAVCLO was the most durable suit; (4) MARCOR with the safety boots placed inside the AES provided the best protection against decreases in toe temperature; and (5) the effectiveness of all AESs evaluated to retain body heat could be improved by increasing the insulation of the suits. The findings from this present study suggest that the optimal AES suit contains a combination of the features prevalent in the AESs we evaluated. Ideally, this suit would be of a whole-body encapsulated design and would possess the ease of entry, waterproof zipper, insulation characteristics of MULFAB, durability and booties of NAVCLO, and boot configuration of MARCOR.

REFERENCES

Allen, J.R., Higenbattam, C., & Redman, P.J. (1985). The effect of leakage on the insulation provided by immersion-protection clothing. Aviation, Space, and Environmental Medicine, 57, 1107-1109.

Bristow, G.K., Sessler, D.I., & Giesbrecht, G.G. (1994). Leg temperature and heat content in humans during immersion hypothermia and rewarming. Aviation, Space and Environmental Medicine, 65, 220-226.

Carpenter, T. (1964). Tables, factors, and formulas for computing respiratory exchange and biological transformations of energy. (Publication 303C). Washington, DC: Carnegie Institution of Washington.

Chen, F., Liu, Z.Y., & Holmes, I. (1996). Hand and finger skin temperatures in convective and contact cold exposure. European Journal of Applied Physiology, 72, 372-379.

Clark, R.E., & Cohen, A. (1960). Manual performance as a function of rate of change in hand skin temperature. Journal of Applied Physiology, 15, 496-498.

Franklin, B.A. (1985). Exercise testing, training and arm ergometry. Sports Medicine, 2, 100-119.

Glickman-Weiss, E.L., Goss, F.L., Robertson, R.J., Metz, K.F., & Cassinelli, D.A. (1991). Physiological and thermal responses of water with varying body compositions during immersion in moderately cold water. Aviation, Space, and Environmental Medicine, 62, 1065-1067.

Goldman, R.F., Breckenridge, J.R., Reeves, C.E., & Beckman, E.L. (1966). "Wet" versus "dry" suit approaches to water immersion protective clothing. Aerospace Medicine, 37, 485-487.

Haffor, A.A., Mohler, J.G., & Harrison, A.C. (1991). Effects of water immersion on cardiac output of lean and fat male subjects at rest and during exercise. Aviation, Space, and Environmental Medicine, 62, 123-127.

Hayward, J.S. (1984). Thermal protection performance of survival suits in ice-water. Aviation, Space, and Environmental Medicine, 55, 212-215.

Hayward, J.S., & Eckerson, J.D. (1984). Physiological responses and survival time prediction for humans in ice-water. Aviation, Space, and Environmental Medicine, 55, 206-212.

Hayward, M.G., & Keatinge, W.R. (1981). Roles of subcutaneous fat and thermoregulatory reflexes in determining ability to stabilize body temperature in water. Journal of Physiology, 320, 220-251.

Hayward, J.S., Collis, M.C., & Eckerson, J.D. (1973). Thermographic evaluation of relative heat loss areas of men during cold water immersion. Aerospace Medicine, 44, 708-711.

Hayward, J.S., Eckerson, J.D., & Collis, M.L. (1977). Thermoregulatory heat production in man: prediction equation based on skin and core temperatures. Journal of Applied Physiology, 42, 377-384.

Hayward, J.S., Lisson, P.A., Collis, M.L., & Eckerson, J.D. (1978). Survival suits for accidental immersion in cold water: design-concepts and their thermal protection performance. Department of Biology, University of Victoria, Victoria, B.C., Canada.

Hodgdon, J.A., & Beckett, M.B. (1984). Prediction of percent body fat for U.S. Navy men from body circumferences and height. (NHRC Technical Report No. 84-11). San Diego, CA: Naval Health Research Center.

Horvath, S.M. (1982). Exercise in a cold environment. Exercise and Sport Sciences Reviews, 9, 221-263.

Kaufman, J., & Dejneka, K. (1985). Cold water evaluation of constant-wear anti-exposure suit systems. (Report No. NADC 8610460). Naval Air Development Center.

Keatinge, W.R. (1969). Survival in cold water. Oxford, England: Blackwell Scientific Publications.

Lewis, S.F., Snell, P.G., Taylor, W.F., Hamra, M., Graham, R.M., Pettingher, W.A., & Blomqvist, C.G. (1985). Role of muscle mass and mode of contractions in circulating responses to exercise. Journal of Applied Physiology, 58, 146-151.

Nunneley, S.A., Wissler, E.H., & Allan, J.R. (1985). Immersion cooling: effect of clothing and skin fold thickness. Aviation, Space, and Environmental Medicine, 56, 1177-1182.

Shannon, M.P., Jacobs, K.A., Ramirez, L.R., Arnall, D.A., Woolf, A.M., Hagan, R.D., Hodgdon, J.A., & Bennett, B.L. (1995). Comparison of anti-exposure suits during rest and arm exercise in cold water. (NHRC Technical Report No. 95-41). San Diego, CA: Naval Health Research Center.

Shender, B.S., Kaufman, J.W., & Ilmarinen, R. (1995). Cold water immersion simulations using the Wissler Texas Thermal Model: validation and sensitivity analysis. Aviation, Space, and Environmental Medicine, 66, 678-686.

Steinman, A.M., Hayward, J.S., Nemiroff, M.J., & Kubilis, P.S. (1987). Immersion hypothermia: comparative protection of anti-exposure garments in calm versus rough seas. Aviation, Space, and Environmental Medicine, 58, 550-558.

Toner, M.M., Holden, W.L., Foley, M.E., Bogart, J.E., & Pandolf, K.B. (1989). Influence of clothing and body-fat insulation on thermal adjustments to cold-water stress. Aviation, Space, and Environmental Medicine, 60, 957-963.

White, G.R., & Roth, N.J. (1979). Cold water survival suits for aircrew. Aviation, Space, and Environmental Medicine, 50, 1040-1045.

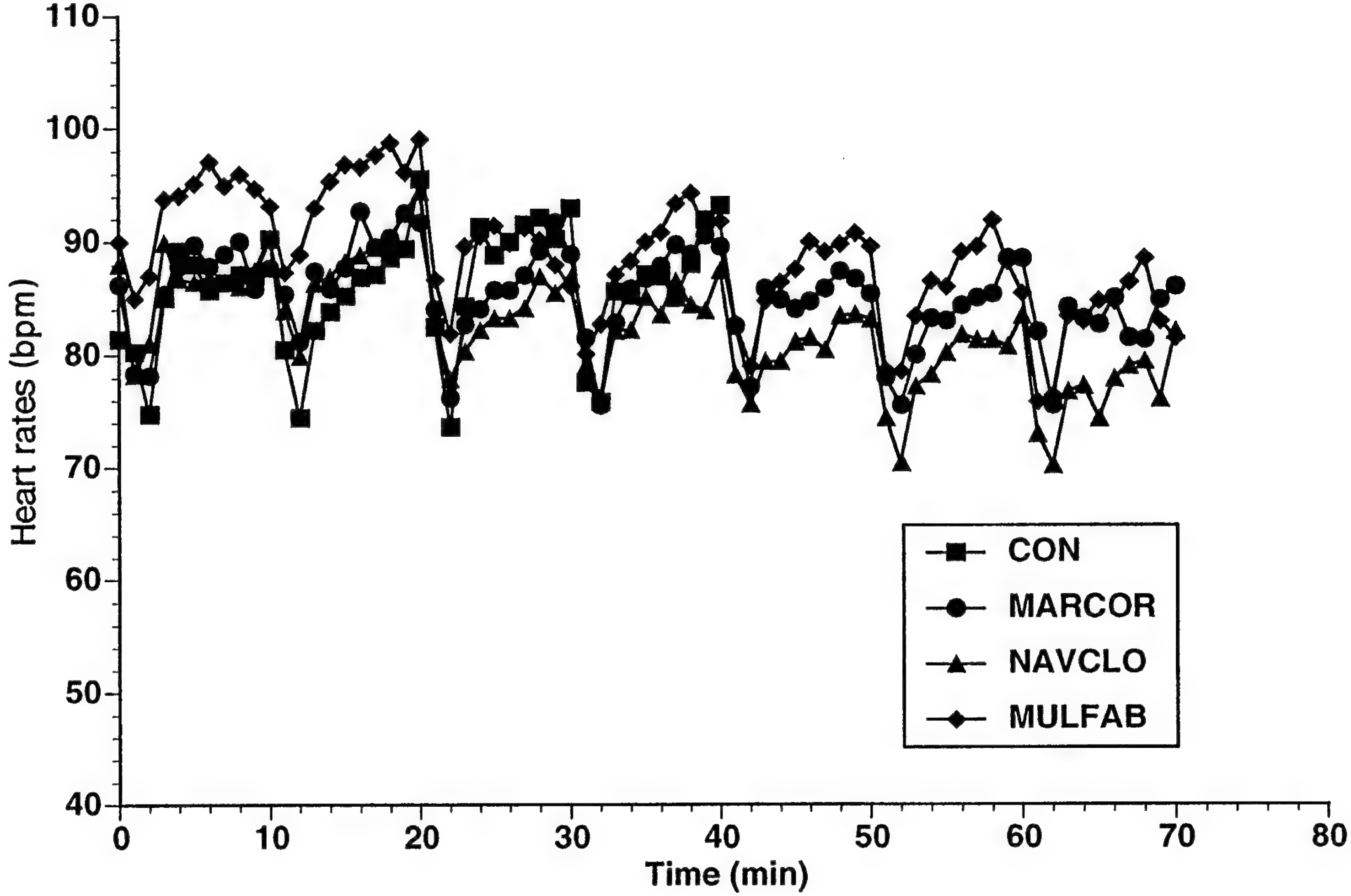

Figure 1. Comparison of mean heart rates (n = 10) among anti-exposure suits up to 70 min of immersion.

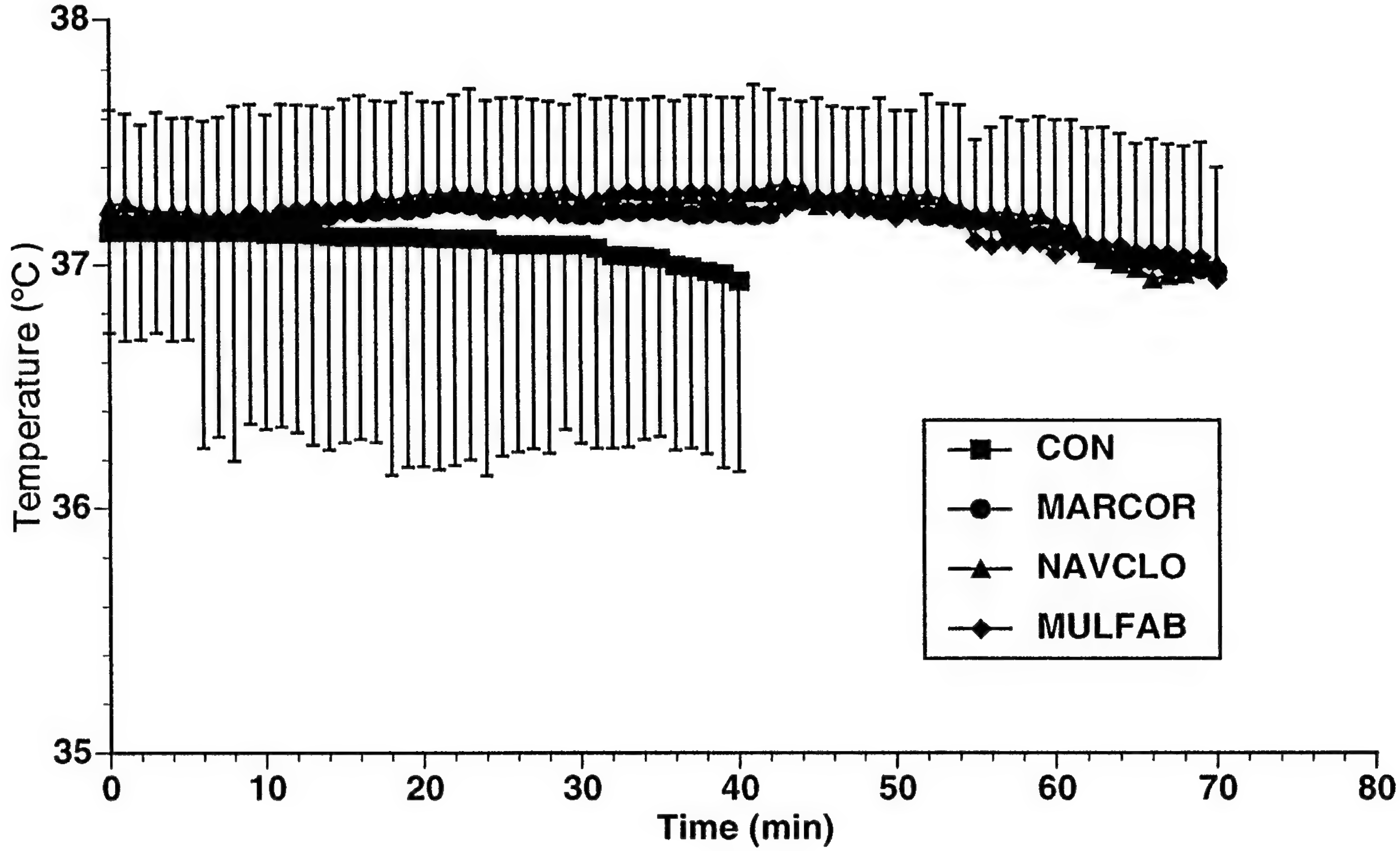

Figure 2. Comparison of mean (± SD) rectal temperatures (n = 10) among anti-exposure suits up to 70 min of immersion.

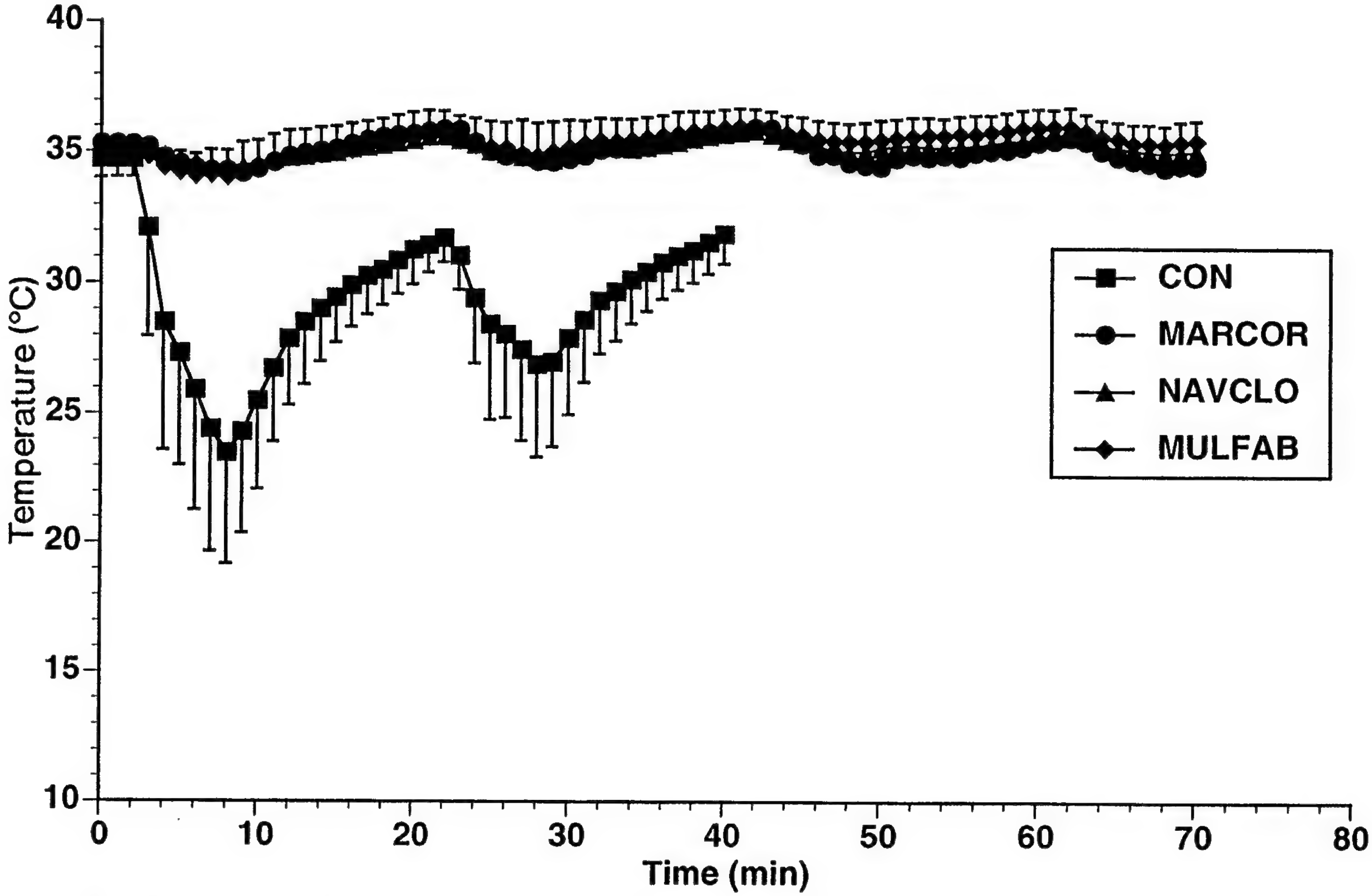

Figure 3. Comparison of mean (± SD) chest skin temperatures (n = 10) among anti-exposure suits up to 70 min of immersion.

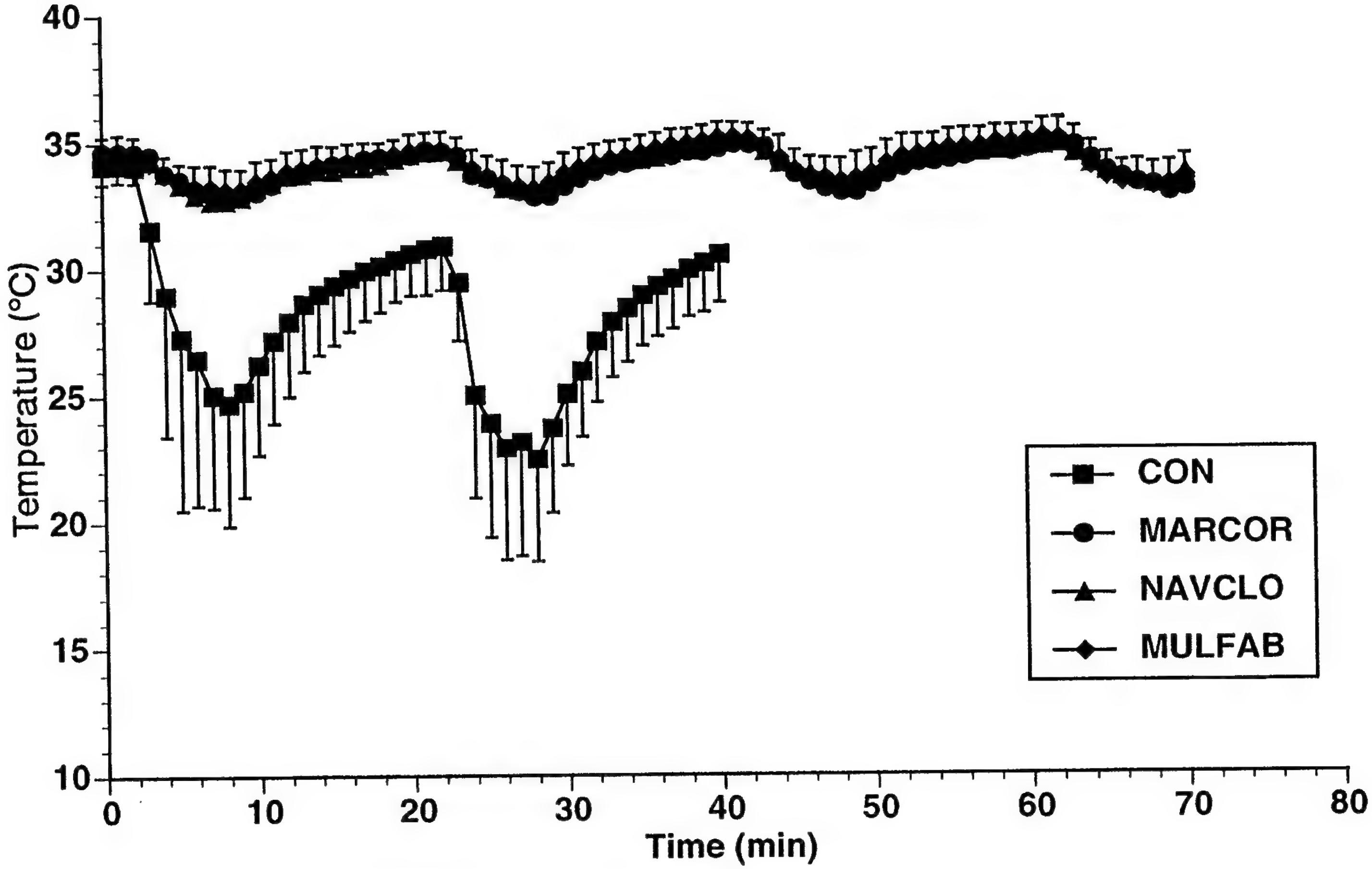

Figure 4. Comparison of mean (± SD) arm skin temperatures (n = 10) among anti-exposure suits up to 70 min of immersion.

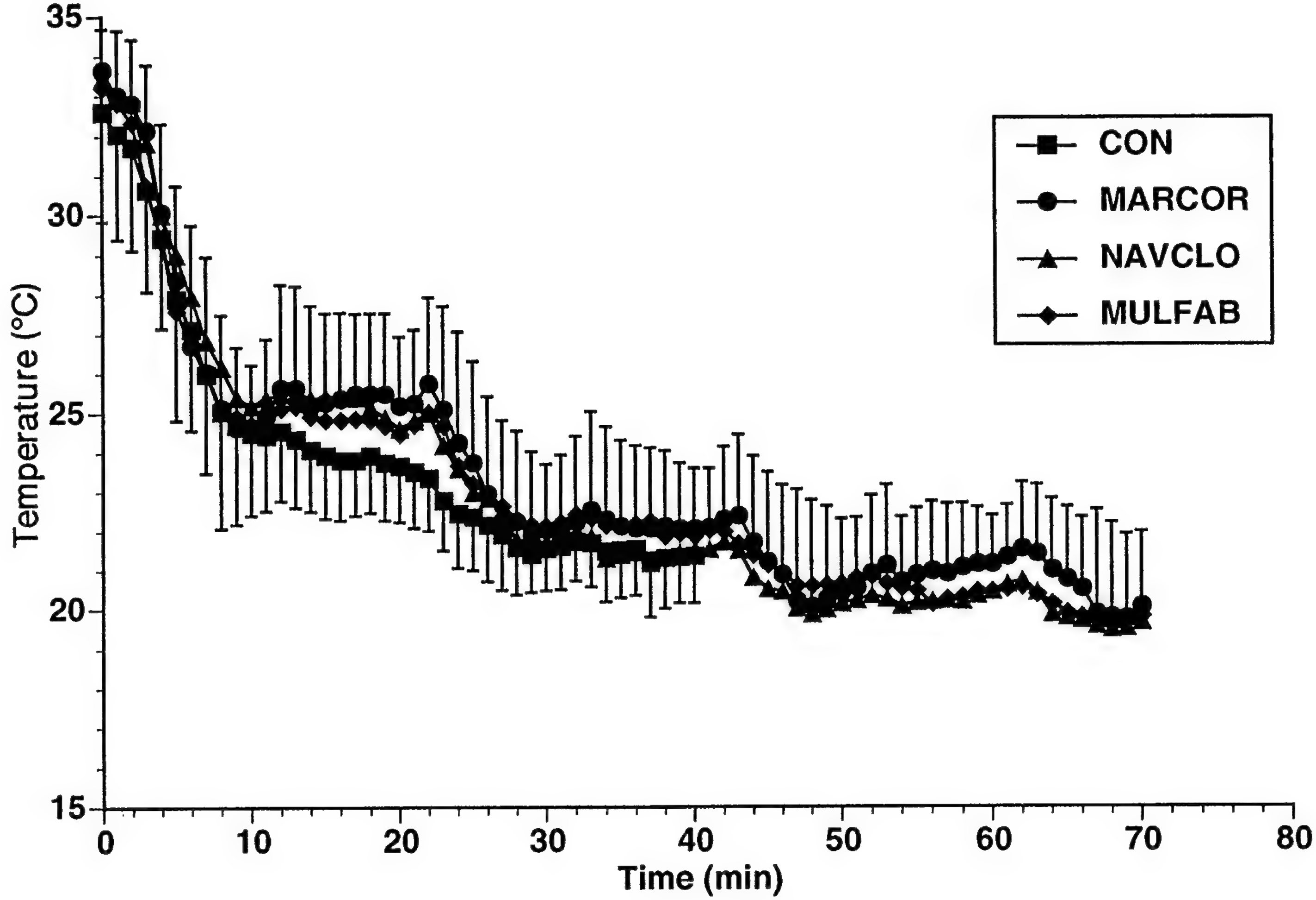

Figure 5. Comparison of mean (± SD) finger skin temperatures (n = 10) among anti-exposure suits up to 70 min of immersion.

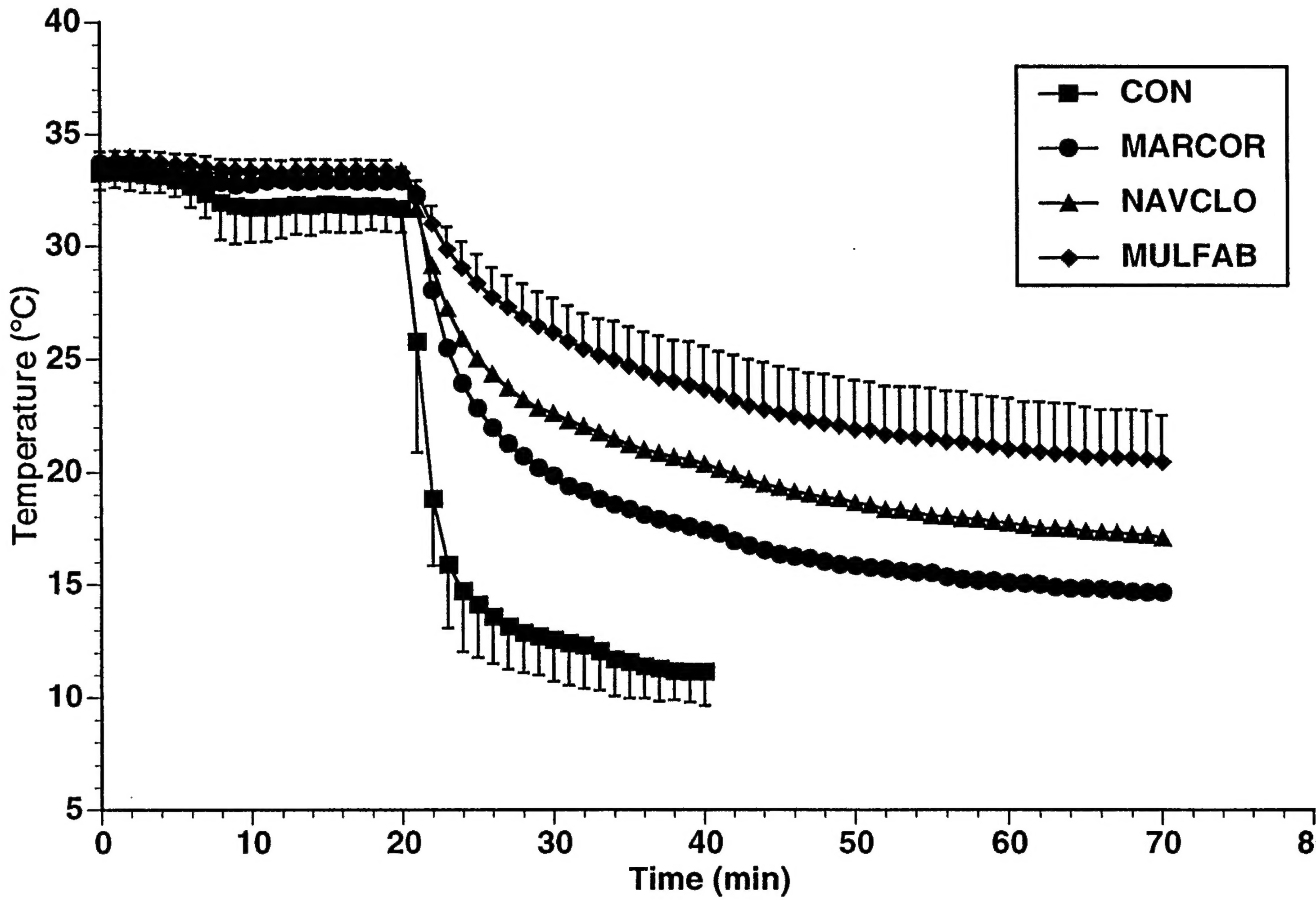

Figure 6. Comparison of mean (± SD) thigh skin temperatures (n = 10) among anti-exposure suits up to 70 min of immersion.

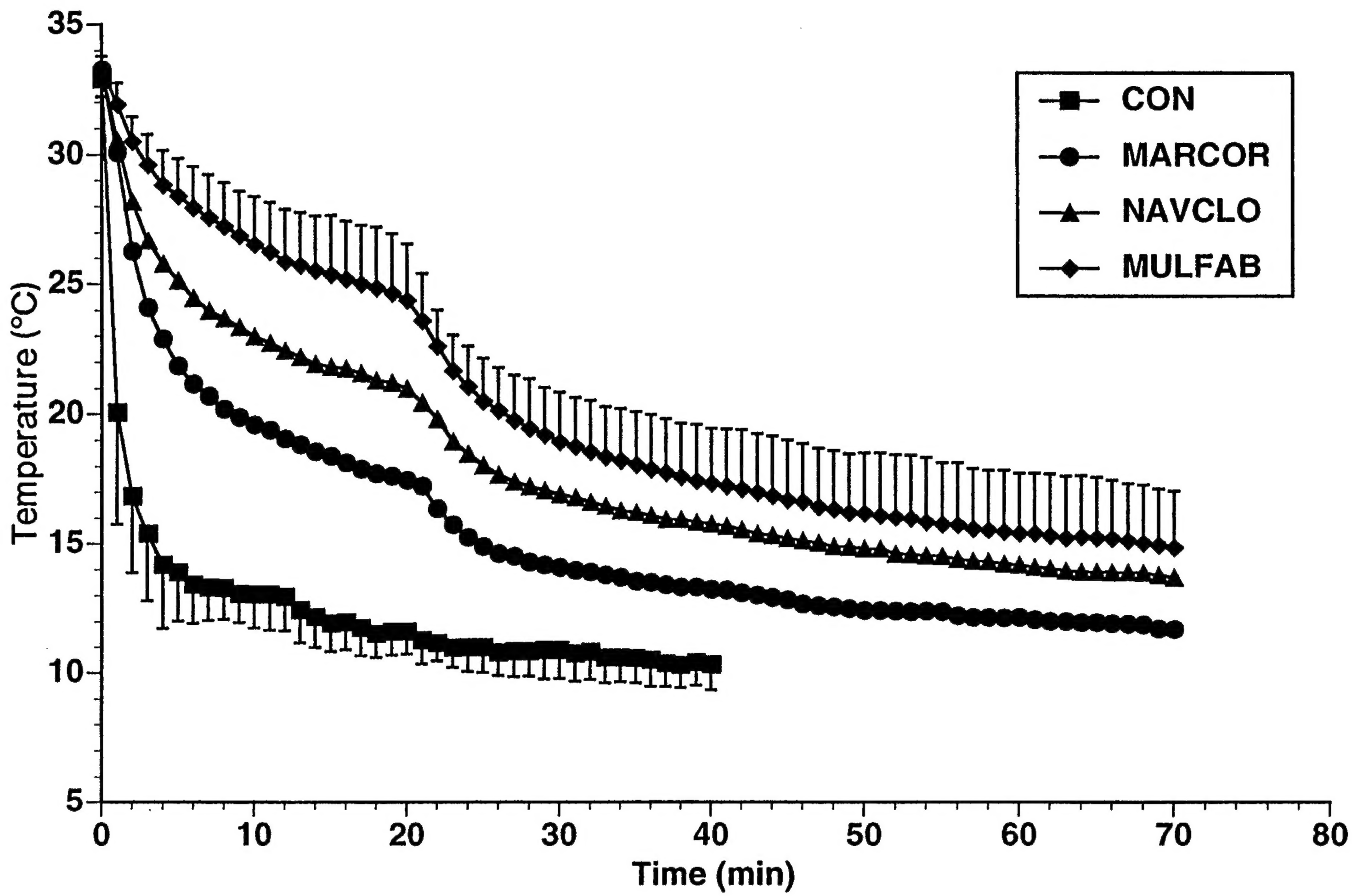

Figure 7. Comparison of mean (± SD) calf skin temperatures (n = 10) among anti-exposure suits up to 70 min of immersion.

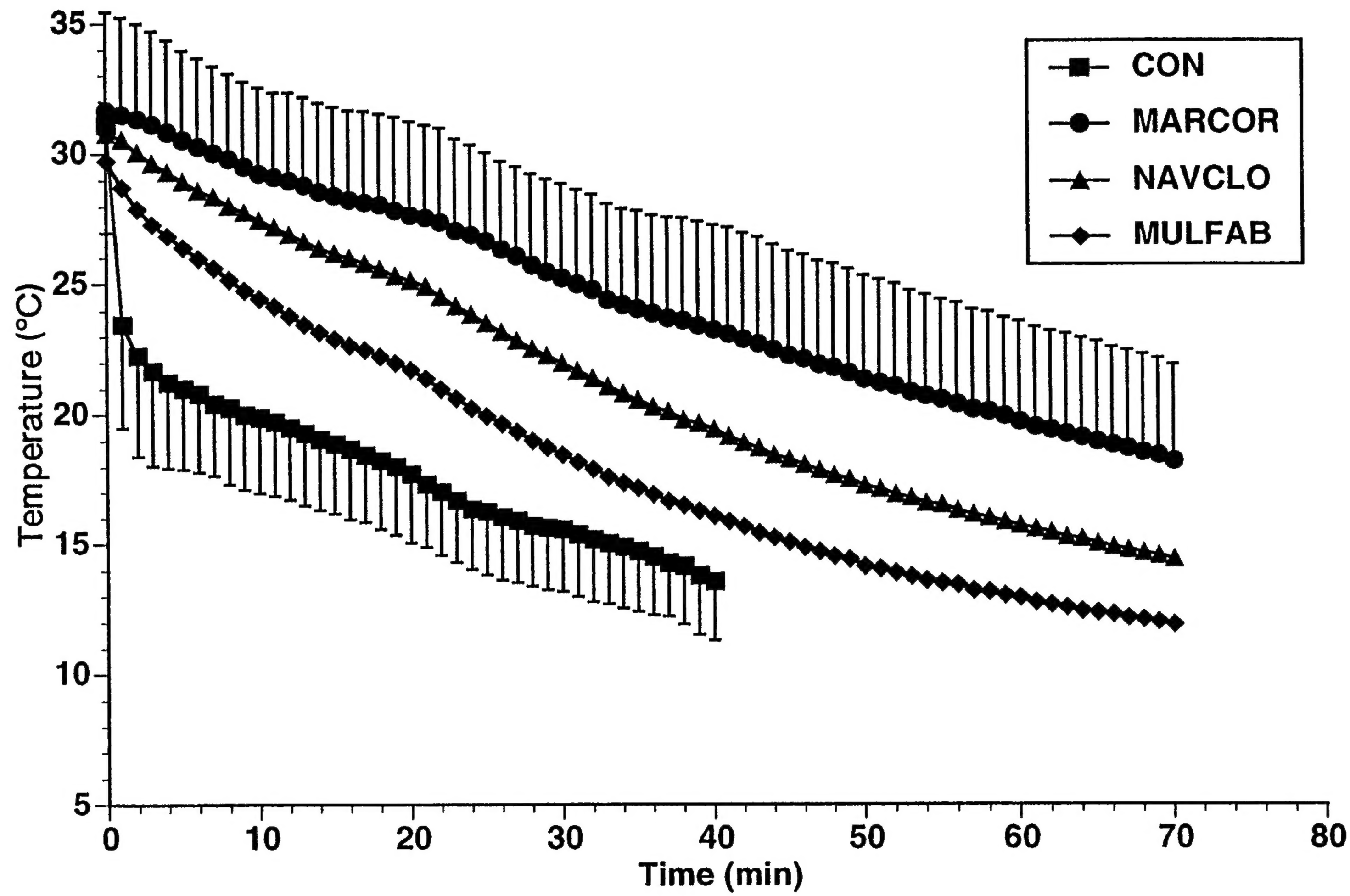

Figure 8. Comparison of mean (± SD) toe temperatures (n = 10) among anti-exposure suits up to 70 min of immersion.

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13. ABSTRACT *(Maximum 200 words)*

This study evaluated the effectiveness of three whole-body anti-exposure suits (AESs) in maintaining body temperatures during immersion in cold water (7.5°C). Male subjects (n = 15) were monitored for rectal (T_{re}), chest (T_{ch}), arm (T_{ar}), thigh (T_{th}), calf (T_{ca}), finger (T_{fi}), and big toe (T_{to}) temperatures during random trials of coveralls (CON), Marine Corps (MARCOR), Naval Clothing and Textile (NAVCLO), and MultiFabs Survival (MULFAB) suits. Coveralls was the undergarment for AES. Immersion was 20 min to knees, 20 min to waist, and up to 40 min to midchest. Consecutively, subjects did 2 min of rest, 6 min of a pipe-patching task, and 2 min of holding 25 lb over head. Maximum immersion time was 80 min. Subjects were able to stay longer ($p < 0.05$) in cold water wearing MULFAB (76 min), NAVCLO (80 min), and MARCOR (74 min) compared with CON (47 min). No differences in final T_{re} ($\bar{X}$=36.8°C) and T_{fi} ($\bar{X}$=20.8°C) occurred among AES and CON. AES T_{ch} ($\bar{X}$s=35.4°C) and T_{ar} ($\bar{X}$s=34.7°C) were higher ($p < 0.05$) compared with CON (29.9°C, 27.5°C, respectively). Final T_{th} for MULFAB (19.4°C) was higher ($p < 0.05$) than NAVCLO (16.0°C) and MARCOR (15.2°C), which were higher than CON (11.5°C). Final T_{ca} for MULFAB (14.7°C) and NAVCLO (13.6°C) were higher than MARCOR (11.2°C) and CON (10.4°C). Final T_{ca} for MARCOR (17.3°C) was higher than NAVCLO (13.2°C), MULFAB (11.6°C), and CON (12.1°C). Thus, MULFAB, NAVCLO, and MARCOR provided the best maintenance of body temperatures.

14. SUBJECT TERMS
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